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^{137}Cs in Whitetailed Deer as Related to Vegetation and Soils of the Southeastern United States

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ABSTRACT

Data are presented for ^{137}Cs in whitetailed deer and vegetation of the southeastern United States along with information as to the nature of the associated soils. The concentrations of ^{137}Cs in some of the vegetation were of sufficient magnitude to account for the ^{137}Cs concentrations found in the deer. The highest ^{137}Cs concentrations in deer were associated with the Humic-Gley soils along the Atlantic and Gulf Coasts. These soils are predominately sandy in nature and have relatively low fixing capacities. The concentrations of ^{137}Cs in the vegetation grown on the Humic-Gley soils under natural and controlled conditions were greater than from the Gray-Brown Podzolic, and Red-Yellow Podzolic soils.

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INTRODUCTION

Considerable work has been conducted with respect to the food-animal-man transfer of ^{137}Cs in the Arctic regions, with caribou and reindeer representing the main animal sources. Until recently, the relatively high concentrations of ^{137}Cs in Arctic caribou and reindeer appeared to be a unique situation. However, concentrations of ^{137}Cs in whitetailed deer from some areas of the southeastern United States (Jenkins and Fendley, 1968) have exceeded the concentrations reported for caribou and reindeer of the Arctic regions (Hanson, 1966; Hanson, et al, 1966; Lidén and Gustafsson, 1966; Lindell and Magi, 1966; Miettinen and Hasanen, 1966; and Nevstrueva et al, 1966).

Because of the extreme difference in the climates of these two regions it would be expected that the sources of ^{137}Cs available to the animals would be different. Therefore, this paper presents soil and vegetation data relative to the ^{137}Cs concentrations in deer of the southeastern United States.

MATERIALS AND METHODS

Deer meat samples were obtained through the deer parasite study of the Southeastern Cooperative Wildlife Disease Study, from Alabama, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Virginia, and West Virginia. Surface soil samples representing a wide range of soils were obtained from

many of the deer collection sites and locations near these sites. These soils were used in a study to determine ^{137}Cs uptake by oat plants with respect to the soil properties. This study was performed in a controlled climate chamber. Vegetation samples were collected from five selected locations (table 2) in Georgia, representing the two major Great Soil Groups and a wide difference in ^{137}Cs deer meat concentrations, to see if the ^{137}Cs vegetation concentrations could account for the ^{137}Cs deer meat concentrations. The deer and vegetation samples were analyzed for ^{137}Cs by means of gamma spectroscopy. Previously published procedures were employed to determine the soil fixing capacity, cation exchange capacity, organic matter, sand, clay, exchangeable potassium, and the ^{137}Cs uptake by oat plants (Black et al, 1965; Cummings et al, 1969; and Jackson, 1958).

RESULTS AND DISCUSSION

Peak concentrations of ^{137}Cs in whitetailed deer from several locations in the southeastern United States are presented in Table 1. Previous work (Jenkins and Fendley, 1968) has shown that peak concentrations occurred in the winter months and decreased to minimum concentrations in the early summer months. Similar seasonal variability has also been observed for caribou and reindeer of the Arctic region (Hanson, 1966, and Liden and Gustafsson, 1966). Peak ^{137}Cs concentrations in caribou and reindeer of the Arctic region are attributed

to lichens which are the predominate food available during a portion of the year. The particular vegetation eaten by deer in the southeastern United States is not as easily defined because of the wide variety of vegetative species available for consumption. The problem is further complicated by changes in the types of vegetation available from one location to another. Therefore, with a number of choices for food, it is very difficult to determine exactly what the deer are eating at any particular time. Thus, it was decided to sample the predominate vegetative species from selected locations to see if the ^{137}Cs concentrations were of sufficient magnitude to account for the peak ^{137}Cs concentrations found in deer. The ^{137}Cs concentrations of the vegetation sampled are presented in Table 2. The higher ^{137}Cs vegetative concentrations are associated with the Humic-Gley soils and the lower ^{137}Cs concentrations with the Red-Yellow Podzolic soils. There are wide differences between the ^{137}Cs contents of the various vegetative species from a given location; however, the ^{137}Cs concentrations are of sufficient magnitude in some of the vetetative species to account for the concentrations found in the deer. This conclusion was reached by a consideration of the buildup of ^{137}Cs in deer by assuming a constant daily intake and that the biological elimination from the deer follows a simple exponential law. The equation that describes these conditions is

$$q = \frac{p}{\lambda} \quad (1 - e^{\lambda t})$$

where q = burden of ^{137}Cs in the deer (nCi);

p = rate of ^{137}Cs intake (nCi/day);

λ = effective decay constant = 0.693/T = 0.023 per day;

T = effective half-life of ^{137}Cs in the deer = $(T_r T_b)/(T_r+T_b)$ (days);

T_r = radioactive half-life (10,950 days);

T_b = biological half-life (30 days);

t = time (days)

After several effective half-lives the buildup of ^{137}Cs in the deer will approach an equilibrium value that is represented by

$$q = \frac{p}{\lambda}$$

The deer body burden of ^{137}Cs (q) is the product of the ^{137}Cs in the deer meat (c) (nCi/kg wet weight), the weight of the deer (w)(kg) and the fraction of the deer weight that is muscle (f_3), divided by the fraction of the ^{137}Cs that is in the muscle (f_2). The rate of ^{137}Cs intake (p) is the product of the ^{137}Cs in the consumed vegetation (x) (nCi/kg dry weight) and the quantity of vegetation consumed (y) (kg/day).

y = 4.5 to 7.0 kg/day (Lidén and Gustafsson, 1966);

w = 40 kg (average weight of the deer collected);

f_2 = 0.62 (Moiseyev et al, 1966);

f_3 = 0.35 (Moiseyev et al, 1966).

An average ^{137}Cs vegetation concentration that would maintain an average ^{137}Cs deer meat concentration of 30.5 nCi/kg for Ware County, Georgia, is

$$x = \frac{(30.5 \text{ nCi/kg})(40 \text{ kg})(0.35)(0.023/\text{day})}{(0.62)(4.5 \text{ kg/day})(0.77)} = 4.6 \text{ nCi/kg}$$

Where 0.77 (Hakonson and Whicker, 1967) is an average fraction of the ^{137}Cs in the vegetation eaten that would be transferred from the digestive tract to other parts of the body. A maximum ^{137}Cs vegetation concentration that will account for the highest ^{137}Cs deer meat concentration (57.1 nCi/kg) from Ware County, Georgia, is

$$x = \frac{(57.1 \text{ nCi/kg})(60 \text{ kg})(0.35)(0.023/\text{day})}{(0.62)(4.5 \text{ kg/day})(0.77)} = 12.8 \text{ nCi/kg}$$

Where 60 kg is a maximum deer weight for this study. Comparing these calculated values with the vegetation values in Table 2 for Ware County, Georgia, it can be seen that these concentrations of ^{137}Cs are available for deer consumption. The values chosen for the second calculation were such that they give a vegetative value that is near a maximum required to account for the highest ^{137}Cs concentration found in a deer at this location. Thus, the lower ^{137}Cs concentrations in deer at this location can be accounted for. Similar comparisons can be made for the other locations where ^{137}Cs vegetative values are available.

An investigation in Florida (Johnson and Nayfield, 1970) has suggested that the ^{137}Cs in gill mushrooms is the major source of

^{137}Cs in deer of that state. This study does not bear out their conclusion. One particular deer food cannot be singled out as the main contributor to the body burdens found in deer. There are several food sources that have high enough ^{137}Cs concentrations (Table 2) to support the body burdens found in the deer.

A factor that may affect the level of ^{137}Cs in deer and possibly change the calculated concentration of ^{137}Cs required in the vegetation, is the metabolic rate of the deer. One experiment (Silver et al, 1969) has shown that the metabolic rate for whitetailed deer from September through April is only 64 percent of what it is for May through August. A decrease in the metabolic rate would decrease the elimination rate of ^{137}Cs, thus leading to a higher ^{137}Cs concentration in the deer. However, the food consumption would probably decrease which would tend to lower the ^{137}Cs concentration in the deer due to a lower intake. Thus, the two factors would work against each other making it difficult to predict the final effect.

Presented in Figure 1 are the peak concentrations of ^{137}Cs in deer meat with respect to the Great Soil Groups (a grouping of specific soils on the basis of a few broad physical and chemical characteristics) for the winter of 1968-1969. It can be seen that the highest values are associated with the Humic-Gley soils along the Atlantic and Gulf Coasts with one exception in Caroline County, Virginia, which is in the Gray-Brown Podzolic group. Since these

soil classifications are on a rather broad basis, it is quite likely that soils in this particular area may have characteristics more nearly like the soils of the Humic-Gley group.

With the nature of the soils appearing to be a major factor connected with the differences in the ^{137}Cs concentration in deer, a controlled environment experiment was performed to determine what soil parameters could best be related to ^{137}Cs plant uptake from the soils. Forty-three soils from the Humic-Gley, Red-Yellow Podzolic and Gray-Brown Podzolic Great Soil Groups were studied using oats as the indicator plant. The results of this study are presented in Table 3 as correlation coefficients for the percentage ^{137}Cs oat plant uptake from the soils with respect to the various properties of the soils. The best correlation was with the soil fixing capacity and the poorest correlation was with the exchangeable potassium. A previous study (Barber, 1964) with six soils and ryegrass showed a linear correlation coefficient of 0.94 between ^{137}Cs uptake and the percent organic matter in the soils. The results of this study do not confirm Barber's finding.

There was an average percentage ^{137}Cs oat plant uptake of 2.82 from 29 Humic-Gley soils and 1.30 from 14 Podzolic soils. The higher ^{137}Cs uptake from the Humic-Gley soils relative to the Podzolic soils is in agreement with the ^{137}Cs concentrations found in the vegetation grown on the Humic-Gley and Red-Yellow Podzolic soils (Table 2).

Although there are many factors that affect the ^{137}Cs concentrations found in deer, from this study it would appear that the nature of the soils is a predominate factor, and the soil fixing capacity a more specific controlling factor. In general, the Humic-Gley soils are of a more sandy nature and have lower fixing capacities than do the Podzolic soils; thus, the higher concentrations of ^{137}Cs in the deer from the Humic-Gley areas are due to the higher ^{137}Cs concentrations in some of the vegetation.

SUMMARY

The highest peak concentrations of ^{137}Cs in whitetailed deer from several locations in the southeastern United States are associated with the Humic-Gley soils along the Atlantic and Gulf Coasts. These peak concentrations can be accounted for through the ^{137}Cs concentrations in several species of vegetation available for deer consumption. A controlled environment study of ^{137}Cs uptake by oat plants from 43 (Humic-Gley, Red-Yellow Podzolic and Gray-Brown Podzolic Great Soil Group soils) soils showed a greater percentage uptake of ^{137}Cs from the Humic-Gley soils than from the Podzolic soils. The soil fixing capacity was more highly correlated with the ^{137}Cs oat plant uptake than any other soil property, thus connecting this particular soil property to the ^{137}Cs concentrations in deer meat.

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Table 1. Cesium-137 Concentration in Whitetailed Deer Meat (nCi/kg Wet Weight)

Location	Collected	Number of Deer Collected	Range	Mean
		Gray-Brown Podzolic*		
Watauga County North Carolina	November 1968	5	1.3 - 3.6	2.6
Randolph County	February 1969	5	0.2 - 2.5	1.6
Alabama	January 1970	5	3.2 - 9.1	6.0
Caroline County	November 1968	5	8.2 - 32.1	21.2
Virginia	November 1969	5	25.0 - 47.3	30.6
		Red-Yellow Podzolic		
Dillon County	February 1969	5	2.2 - 8.1	4.6
South Carolina	February 1970	5	6.0 - 10.3	7.0
Greene County	November 1968	17	0.2 - 18.1	6.8
Georgia	November 1969	21	0.2 - 5.2	2.4
Decatur County Georgia	December 1968	12	1.2 - 8.7	4.7
Dougherty County Georgia	December 1968	8	0.7 - 8.0	2.9
Louisiana	January 1969	10	0.2 - 3.7	2.0
Mississippi	February 1969	2		5.5
		Lithosols		
Collier County Florida	October 1968	5	2.5 - 17.5	7.2
		Humic-Gley		
Liberty County	January 1969	5	23.6 - 44.4	32.9
	November 1969	5	51.7 - 75.3	61.9

(continued)

Table 1 continued

Location	Collected	Number of Deer Collected	Range	Mean
		Humic-Gley		
Ware County Georgia	December 1968	9	28.7 - 82.0	53.1
	December 1969	7	15.0 - 57.1	30.5
Clinch County Georgia	December 1968	7	15.3 - 63.4	29.2
	December 1969	44	11.7 - 65.1	34.8
Walton County Florida	February 1969	8	28.6 -107.8	55.3
Beaufort County South Carolina	December 1968	11	8.5 - 51.4	25.2
	December 1969	15	0.2 - 72.0	16.0
Carven County North Carolina	December 1968	10	9.0 - 64.5	31.1
Marion County Florida	January 1969	9	48.0 -119.7	82.7
Clay County Florida	December 1968	5	17.3 - 30.3	24.2

Table 2. Average Cesium-137 Concentration in Vegetation (nCi/kg Dry Weight)

Location	Species	1969 September	1969 December	1970 February	1970 June
	Humic-Gley*				
Ware County Georgia	Mixed grasses	6.5	3.7	--	13.2
	Redbay leaves	18.7	22.7	--	13.2
	Gallberry leaves	1.2	0.8	--	0.4
	Waxmyrtle leaves	1.0	1.0	--	1.6
	Palmetto berries	20.4	--	--	--
	Palmetto shoots	--	--	--	20.4
	Smilax	1.0	--	--	--
Clinch County Georgia	Mixed grasses	4.4	--	--	--
	Redbay leaves	12.1	--	--	--
	Gallberry leaves	1.4	--	--	--
	Waxmyrtle leaves	3.7	--	--	--
	Palmetto berries	13.1	--	--	--
	Smilax	2.2	--	--	--
	Honeysuckle	0.8			
Liberty County Georgia	Mixed grasses	--	--	4.2	--
	Redbay leaves	--	--	13.4	--
	Gallberry leaves	--	--	1.1	--
	Waxmyrtle leaves	--	--	1.3	--
	Red-Yellow Podzolic				
Dougherty County Georgia	Mixed grasses	2.4	--	--	--
	Waxmyrtle leaves	0.3	--	--	--
	Smilax	0.3	--	--	--
	Honeysuckle	0.5	--	--	--
	Sumac	0.8	--	--	--
Greene County Georgia	Mixed grasses	0.2	0.3	--	--
	Smilax	0.2	0.2	--	--
	Honeysuckle	0.3	0.2	--	--
	Sumac	0.1	0.2	--	--

* Great Soil Groups

Table 3. Correlation Coefficients

	Correlation Coefficient	Type of Equation
Percent ^{137}Cs Uptake vs. Soil Fixing Capacity	- 0.74	Power
Percent ^{137}Cs Uptake vs. Percent Clay	- 0.64	Power
Percent ^{137}Cs Uptake vs. Percent Sand	0.48	Linear
Percent ^{137}Cs Uptake vs. Cation Exchange Capacity	- 0.31	Power
Percent ^{137}Cs Uptake vs. Percent Organic Matter	0.29	Linear
Percent ^{137}Cs Uptake vs. Exchangeable Potassium	- 0.11	Linear

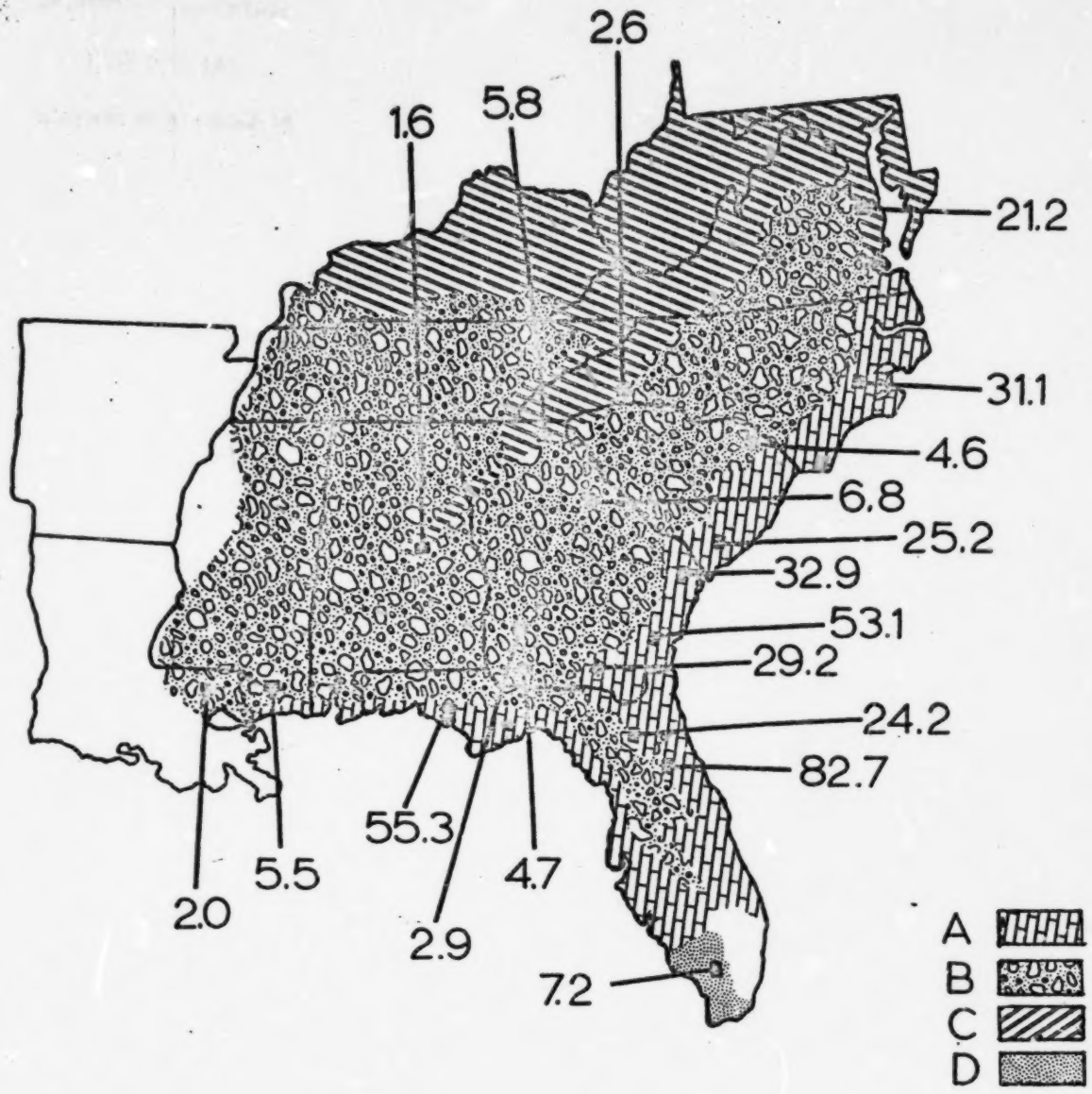

Figure 1. Peak concentrations of ^{137}Cs in whitetailed deer meat (nCi/kg wet weight; winter 1968-69) with respect to Great Soil Groups. A—Humic-Gley soils, B—Red-Yellow Podzolic soils, C—Gray-Brown Podzolic soils, and D—Lithosols.